A meta-analytic review of the relationship between neurocognition, metacognition and functional outcome in schizophrenia

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Abstract: Previous research has identified that neurocognition predicts functional outcome in schizophrenia to a greater extent than psychopthology. More contemporary authors have begun to explore the role of metacognition as a mediating variable between neurocognition and functional outcome. The present review sought to extend the known work by synthesising the results reported in individual studies to see if these results are consistently found across samples. Relevant search strategies were entered into Medline (PubMed), PsychINFO and Embase. The present meta-analysis encompassed 17 studies (N=1060) investigating the relationship between neurocognition and metacognition and 7 studies investigating the relationship between metacognition and functional outcome (N=645). A small-to-moderate mean effect size was found between neurocognition and metacognition (effect size range .13 -.58,) and a small-to-moderate effect size was found between metacognition and functional outcome (range .17 - .57). Study findings suggest that relationships between variables are consistently found across samples and that future research should focus on investigating this relationship at earlier stages of illness, in female cohorts and across cognitive domains. Greater investigation is required in functional outcome, differentiating the impact of metacognition on functional capacity and other domains of functional outcome.

Introduction

Cognitive impairment in schizophrenia is a core deficit of the disorder (Heinrichs & Zakzanis, 1998) and observed across prodromal (Jahshan et al., 2010), first-episode (Mesholam-Gately et al., 2009) and into remission stages (Hoff et al., 2005) Whilst cognitive deterioration has generally not been found to be progressive in first-episode psychosis (FEP) (Leeson et al., 2011), improvements after illness remain diminutive in certain domains such as IQ, working memory and processing speed (González-Ortega et al., 2012). Cognitive performance has also been implicated in predicting functional status in people with schizophrenia (Tolman & Kurtz, 2010) and found to be a better determinant of outcome than psychopathology (Green, 1996). Green, Kern and Heaton (2004) in a review, report cognitive impairment to explain between 20-60% of variance in outcome with Couture, Penn, and Roberts (2006), in further review positing that studies exceeding 40% of variance were very much the exception.

The relationship identified between cognitive ability and community function led to the development of cognitive remediation programmes with the aim of improving the cognitive skills possessed by those with a diagnosis of schizophrenia to improve their community functioning. Despite some gains in function from remediation initiative (Wykes et al., 2007), not all of the skills necessarily translated into real-world improvements (Wykes et al., 2012) and led researchers to look for mediating variables to account for this relationship. Studies have suggested social cognition (Addington, Saeedi & Addington, 2006), social discomfort (Bell et al., 2009), defeatist beliefs (Grant & Beck, 2009), intrinsic motivation (Nakagami et al., 2008) and negative symptoms (Couture, Granholm & Fish, 2011) as potential mediating variables between neurocognition and outcome. Proposed variables however have not yet provided conclusive results and much of the relationship between neurocognition and functional outcome still remains unaccounted for (Fett et al., 2011). One approach has been to implicate metacognition in this model (Lysaker et al., 2010a) and research has begun to explore the relationship between neurocognition and metacognition. By improving an individual's metacognitive abilities, the cognitive skill improvements can potentially be integrated into social and occupational situations (Lysaker et al., 2010a).

Metacognition refers to the cognitive processes involved in thinking about thinking (Flavell, 1979) and incorporates how we monitor and control, slave cognitive mechanisms (Frith, 2012). Most models of metacognition propose a multi-level hierarchical system, with a higher order theory and knowledge based (Koriat & Levy-Sadot, 1999), meta-level processing (Nelson & Narens, 1994) comprising of explicit, effortful processing (Frith, 2012) and the synthesis of complex information to compile a representation of one's own cognitive world (Lysaker et al., 2008). This higher-order metacognitive knowledge interacts with lower-order subjective experience-based (Koriat & Levy-Sadot, 1999), automatic, implicit (Frith, 2012) metacognitive judgements to regulate object-level processing units. Metacognition involves the ability to have an awareness of and monitor one's own mental states, consider the fallibility of cognitive products and be able to form, revise and so control one's mental states in rapidly evolving contexts (Lysaker et al., 2010b). Thus metacognition potentially draws upon memory, working memory and executive monitoring and control processes.

An inability to integrate ideas about oneself and others may lead to misinterpretation of social situations and avoidance of participating in them (Lysaker et al., 2011a). The inability to consider the bigger picture and one's role in it may lead to the poor identification and solving of social and psychological problems (Lysaker et al., 2011b). Thus a deficit in the ability to access metacognitive knowledge may leave individuals with basic evolutionary responses such as fight-or-flight to respond to challenges and frequent employment of anxious arousal and hyper-vigilance (Gilbert, 2001). The ability to produce an accurate representation of one's cognition and to reflect back on it will lead to improved control over cognition and better application of neurocognition to the real world (Lysaker et al., 2011a). Thus improved metacognitive knowledge will lead to improved functional outcome in the community.

Whilst neurocognitive deficits have proven links to impoverished psychosocial function (Green et al., 2000), metacognition may offer an explanation in addition to neurocognition. Despite being considered relatively trait-like in schizophrenia (Lysaker et al., 2014), metacognitive capacity is impacted by situational, cognitive and emotional demands (Dimaggo et al., 2009) and may therefore impact differently on capacity to complete daily tasks and actual real-world functioning.

Previous studies have included varying measures of both metacognition and functional outcome each with differing design problems. Functional capacity is the ability to successfully simulate everyday tasks under observation from a researcher. Capacity measures only assess the ability to conduct a task but not whether these are employed in real-life (McKibbin et al., 2004) and self-report measures of outcome are victim to bias and level of insight (Atkinson, Zibin & Chuang, 1997). Likewise, studies have often employed individual measures of metacognition (see table 1) and investigating whether these relationships to functional outcome are observed across metacognitive domains would therefore be valuable to understand.

Study aims

The primary goals of this review will therefore be to a) identify the patterns across studies for the relationship between neurocognition and metacognition, and b) to assess the overall relationship between metacognition and functional outcome across studies, through a meta-analytic technique.

Method

Studies investigating the relationship between neurocognition and metacognition were identified through a computerised search of the electronic databases Medline (PubMed), PsychINFO and Embase incorporating publications from the years 1983-2016. The syntax (schiz$ OR psychosis) AND (cogn$ or neurocogn$) AND (metacogn$) was included in the search strategy. The term metacogn$ was decided upon due to the ambiguity in definition across research disciplines and the potential for the term metacognition to serve as an umbrella term for a host of processing avenues. The present review as an exploratory paper adopted this more rigid definition to ensure clarity in inclusion criteria. Studies investigating the relationship between metacognition and functional outcome were also identified through a second computerised search with the syntax (schiz$ OR psychosis) AND (metacogn$) AND (function$). A secondary search of the grey literature to find unpublished data and PhD dissertations was completed with no additional papers found. Duplicate articles were removed, articles not written in English, editorials, study protocols, non-human populations, articles published solely in abstract form and conference proceedings and dissertation articles were also removed. Review articles and meta-analyses were excluded however the reference lists were systematically explored to ensure that any further articles missed in the original search strategy were included in the review. The retrieved studies' abstract and reference sections were hand-screened for additional citations.

Articles employing the metacognition assessment scale (MAS) and the Beck cognitive insight scale (BCIS), were grouped together as measures of metacognition. Self-reported measures of function have been shown to be victim to confounding factors such as insight, depression (McKibbin et al., (2004) and psychopathology (Atkinson, Zabin & Chuang, 1997) therefore only clinician-rated and objective measures of function were included in the overall analysis.

To assess how specific cognitive domains relate to metacognition, a secondary analysis was conducted exploring how memory, executive function and verbal IQ relate to metacognition individually. This may rule out one domain driving the relationship rather than neurocognition generally.

Statistical analysis

The observed correlations from each study were subjected to Fisher's r-to-z transformations as advised by Hedges and Olkin (1985). The z-transformed correlations were then weighted by their inverse standard error. The sum of weights and sum of weighted effect sizes were calculated to produce the weighted mean effect size and heterogeneity was investigated using the Q and I^2 statistic. Q statistics were then compared to critical values to ensure no violations of homogeneity. Confidence intervals were calculated for all studies in addition to mean effect sizes. A random effects model was employed (Hedges & Olkin, 1985) and results (Z_r) were transformed back to the r-metric prior to reporting.

Results

The relationship between neurocognition and metacognition

[Insert table 1 here]

The literature search identified 17 final papers that reported a relationship between neurocognition and metacognition. Based on findings from Lysaker et al (2013), who found that the MAS and BCIS measures loaded on the same component in a Principle Component Analysis (PCA), these variables were combined in the current paper, when considering the relationship between metacognition and both neurocognition and functional outcome. Neurocognition was measures by the WCST in six studies, the WAIS vocabulary scale in four studies, a neurocognition composite score in 3 and the DKEFS sorting task, HVLT, NART and WMS in one study each. Metacognition was measured with the MAS in 12 studies, the BCIS in four and a combined factor of both in one final study.

The papers all included adult schizophrenia samples except for one FEP paper, with the majority using a DSM-IV diagnostic criteria. The mean age of participants included in the review was 42.35 (range 23.2-50.5).

[Insert figure 1 here]

Metacognition measurement

Metacognition was measured through two methods in the papers included. The MAS uses the Indiana Psychiatric Illness Interview (IPII), a semi-structured interview designed to explore narratives of both the self and illness in those with schizophrenia. The interview is designed to be conversational and participants are required to generate a personal narrative and self-reflect which can be analysed in terms of metacognitive capacity. The scale is comprised of 4 subscales;

understanding one's own mind or *self-reflectivity*, *understanding others' mind*, *mastery* and *decentration*. A higher score translates to better metacognitive ability (see Lysaker et al., 2007) for validity and reliability information). The MAS appears to assess synthetic forms of metacognitive processing which are effortful, deliberate, naturally occurring within a personal narrative.

The Beck Cognitive Insight Scale (BCIS) is a 15-item questionnaire assessing how participants assess their own judgements. The measure contains two subscales; *self-reflectivity* and *self-certainty* relating to the ability to reflect back on cognition and confidence in cognitive products. An overall score of cognitive insight or *composite index* score is obtained by subtracting the self-certainty score from the self-reflectivity score (see Beck et al., (2004) for scale validation). The BCIS is a general reflection upon one's thinking and is not context specific.

Neurocognition and metacognition

An initial analysis was run to investigate the relationship between neurocognition and metacognition. Only one effect size from each paper was included to prevent the sample population being included twice. In the situation where two cognitive tasks were available from the same cognitive domain for a paper, the most commonly reported measure's effect size was selected to match other papers in the analysis.

[Insert figure 2 here]

Effect sizes were extracted from 17 papers. Effect sizes for the relationship ranged from -.25 -.58 and a total of 1060 participants were pooled. The Q statistic was non-significant (Q=16.45, df=16, p>.05) and I^2= 0.03 suggesting homogeneity of variance. The Z statistic suggested a significant relationship between neurocognition and metacognition (Z= 6.43, p<.001) and a mean effect size of .29 (95%+/- CI: .21, .38) suggested a moderate positive relationship existed between the variables. The study effect sizes and confidence intervals are available in figure 2 above.

In regards to publication bias, the fail-safe N suggested that 519 studies with 0 effect sizes would need to exist to dissolve this significant effect and Kendall's Tau also suggested little evidence for publication bias (τ(N=17)=.15 p=.409). The funnel plot is available in figure 3 below.

[Insert figure 3 here]

The relationship between metacognition and functional outcome

[Insert figure 4 here]

Table three contains the individual study information for those included in the meta-analysis of the relationship between metacognition and functional outcome. Metacognition was measured through a variety of methods in the papers included. Three of the studies included the Metacognition Assessment Scale (MAS) as their measurement of metacognitive processing, two the WCST-meta paradigm, one the Beck Cognitive Insight Scale and a final paper used a factor comprised of the MAS and BCIS scales.

In relation to functional outcome, three studies employed the Global Assessment of Functioning (GAF) measure, two more the Quality of Life (QoL) interpersonal relations measure which is a semi-structured interview assessing the frequency of social contacts , one study used the UPSA performance-based functional capacity measure and one used the Specific Levels of Functioning (SLOF) interpersonal functioning subscale, an interviewer-rated assessment of functioning.

[Insert table 2 here]

The seven studies included for the meta-analysis had an effect size range of 0.17 to 0.57 and the total sample size was 645. The Q (Q= 65.09, df=6, p>.05) and I^2 (I^2= 0) statistic suggest homogeneity was present across study domains indicating that there was not a significant difference in effect sizes found across studies. The mean effect size across studies was .24, the confidence intervals ($CI_{.95}$) were .17 (lower) to .31 (upper) and a highly significant associated Z score between studies was also observed (z= 6.11, p=<.001). The forest plot with individual study and mean effect size and confidence intervals is available in figure 5 below. This infers a small-moderate positive effect size (Cohen, 1992) between metacognitive ability and function such that increased metacognitive ability is associated with higher function.

[Insert figure 5 here]

An inspection of the fail-safe N value indicates that there would need to be 95 unpublished studies with 0 effect sizes to ameliorate the significant effect found and an inspection of Kendall's Tau suggests little publication bias (τ(N=7)=.52 p=..099). Despite a small number of studies being present, the funnel plot provides corollary evidence for no significant publication bias being present (see figure 6 below).

[Insert figure 6 here]

Sub-domain analysis

[Insert table 3 here]

Discussion

The results indicate that dysfunctional metacognitive processing is associated with impoverished cognitive processing as demonstrated in cross-sectional studies gathered from the last 15 years. The individual meta-analysis results indicate a moderate effect size for neurocognition on metacognitive processing. The second analysis confirms that there is a small-moderate relationship between metacognition and functional outcome across studies.

The relationship between neurocognition and metacognition

Firstly, an overall significant relationship was found between combined measures of neurocognition and metacognition and a small-to-moderate mean effect size was reported. In relation to individual cognitive domains and metacognition, executive function was the most frequently investigated domain. In terms of metacognitive knowledge, conceptually the relationship makes sense. In order to produce and form accurate beliefs about mental states, a series of cognitive abilities (recall, emotional recognition) are required, however in order to do this successfully, one must be able to monitor, inhibit irrelevant information, and switch between belief sets to judge and reflect. Likewise, in relation to the BCIS, executive function in addition to memory may be required in order to hold contextual information online to assess judgements and notice distortions or erroneous outputs/conclusions. The vocabulary subscale of the WAIS was the second most employed measure of neurocognition in the present study. In order to recall and describe the synthesis of internal and external mental states vocabulary is required to compose the narrative. The vocabulary subset of the WAIS is also employed as a proxy measure of pre-morbid IQ function. This suggests that IQ prior to becoming unwell may also underpin successful metacognitive processing; those that retain their premorbid IQ may be better able to inspect cognitive states and put them in perspective. Working Memory has certainly been associated with the MAS as, in order to reflect on mental states, these mental states need to be held in working memory in the first instance. These relationships were all found in the smaller, cognitive subdomain meta-analyses (table 3).

The relationship between metacognition and functional outcome

The results of the second meta-analysis indicate that metacognitive processing has a small to moderate sized effect on functional outcome in schizophrenia. Furthermore, these individual effects observed in preliminary studies are consistently found across designs. This relationship was found across clinician-rated measures of outcome and capacity based measures however it must be noted that only one paper in the review addressed the latter. Put simply, better metacognitive abilities relate to better functional outcome in those with a diagnosis of schizophrenia as demonstrated across a larger participant pool in the present study. Having the ability to integrate and reflect on one's cognition, and use this skill to manage social interactions, may be critical to managing relationships and occupational recovery. These metacognitive abilities may be more pertinent skills to successful community integration than cognitive ability alone. Interestingly, O'Connor and colleagues (O'Connor et al., 2013) found that once negative symptoms, ethnicity and gender were controlled for in analysis, this relationship between metacognition and outcome was not significant. This may be reflective of the measure used (cognitive insight) having a more pronounced impact on function longer term whereas symptoms are a better predictor of functioning in the short term.

Despite the few studies included in this exploratory meta-analysis, there is little indication of publication bias and a large number of unpublished studies would need to be present in order to ameliorate the observed relationships found in the analyses.

Limitations

As with all meta-analyses, there were some systemic problems in the data included in analysis. Firstly, due to different study designs, the analysis had to find a balance between conceptual integrity when combining variables, and running analysis on a meaningful amount of data. The neurocognition and metacognition analysis was conducted on 17 studies however the measure of neurocognition included varied between studies. Whilst there is preliminary evidence to suggest that the MAS and BCIS are homogenous in measurement (Lysaker et al.,, 2013), more work needs to be completed in the area to improve confidence in this conceptual alignment.

The lack of consistently employed, standardised measures makes cross-study comparisons difficult (Green et al., 2008). There has been a consensus in schizophrenia research to address this problem and great steps have been made in introducing the MATRICS neurocognitive battery (Nuechterlein et al., 2012) however the studies reported in this review have yet to benefit from this initiative. Likewise, even studies employing the MAS tended to report different subscales, and infrequently total scores, which prevents an assessment of the influence of differing cognitive domains on different aspects of metacognitive function.

A final problem was found in the sample descriptions; whilst some studies reported that the sample recruited was from a higher-functioning cohort, some of the studies employed different diagnostic entry criteria and some gave little description other than 'persons with schizophrenia'. Thus it is difficult to claim with certainty that similar clinical profiles are being compared. Likewise, only one of the studies was completed in FEP (Lepage et al., 2008); whilst work on both neurocognition (Mesholam-Gately et al., 2009) and metacognition (Macbeth et al., 2014; Davies, Greenwood & Fowler, 2016) have been investigated in FEP, the relationship between neurocognition, metacognition and functional outcome specifically has not. Lepage and colleagues (2008) found no significant relationship between the BCIS and memory however whether this is symptomatic of the relationship having not manifest in early-onset samples or whether this was due to measure selection is hard to elucidate due to the dearth in studies.

One of the main problems identified in the literature is capturing the nature of functioning in schizophrenia. In four of the studies, functioning was assessed by self-report or a clinician-rated measure which may be victim to confounding variables such as clinical insight. Performance-based measures are being suggested as a better measurement of function (Depp et al., 2012) however only one study in the present review assessed functional outcome this way (Lysaker et al., 2011a).

Whilst the inspection of publication bias did not highlight any significant 'file-draw' problems, studies did not always report all of the gathered data across constructs. The full reporting of different aspects of outcome and refraining from the use of composite aspects of function would make comparisons more meaningful. Symptom measurement would prove important to include in analysis across studies as well but studies varied in both the measurement and data reported for this variable.

Future directions

One of the main suggestions made in the studies included in the present review relates to future studies needing to replicate findings in different cohorts such as first-episode. A plethora of studies list sample selection as a potential problem, with schizophrenia samples largely comprised of middle-aged, chronic presentation, males. The relationships found may in part be due to differing treatment exposures, neuroleptic medication therefore replication must be made in more diverse samples such as those at first-episode, those refusing treatment and female participants. For example, neuroleptic medication has been demonstrated to impair processing speed in schizophrenia (Veselinovic et al., 2013) and processing speed has been linked to both working memory and executive function. Whether the deficits observed in these domains is due to cognitive impairment or impairment due to medication exposure would be valuable to investigate. The effect of the aforementioned potential confounding variables may be reduced with recruitment in early-onset samples. Future researchers need to employ multiple measures of both neurocognition and metacognition across longitudinal designs to really elucidate the relationship between these concepts. There also appears to be a dearth in research investigating environmental factors and their relationship to metacognition in schizophrenia, future work may benefit from considering the role of sociodemographic factors in analysis.

Conclusions

In conclusion, the present meta-analysis found small-to-moderate effects between neurocognition and metacognition and small-to-moderate relationships between metacognition and functional outcome. The present review bolsters the theory that neurocognition is a pillar stone upon which metacognition is built, and this relationship is found across studies consistently. The present review extends this for the first time to demonstrate that metacognition is related to functional outcome in schizophrenia across studies. These findings enable a better understanding of the mechanics driving individual recovery in function with schizophrenia and may be used to elucidate further the known relationship between neurocognition and functional outcome. Aspects of metacognition have the scope to contribute to the ability for an individual to return to work, maintain social relationships, live independently and manage symptoms in the community however this relationship needs further exploration and refinement. Questions remain about the manner in which negative symptoms (also implicated in functional outcome) interact with metacognition and functional outcome, and how these relationships change over time and through recovery. Potentially symptoms may be more predictive of cross-sectional functioning[39] however longer-term, metacognition may be of importance once symptoms have been addressed. By understanding the relationship further, cognitive remediation and metacognitive behavioural therapy can be focused and refined to give those with a schizophrenia diagnosis the raw skills to regain their functional abilities.

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Tables

Table 1: Search results for neurocognition and metacognition

Study	N	Diagnosis	Mean age (SD)	% female	Design	Cognitive domain(s)	Metacognitive domain(s)
Lysaker et al., (2005)	61	DSM-IV schizophrenia/schizoaffective	47.7(6.8)	0	Cross-sectional	**WAIS III (V**, DS) WMS III (VR) HVLT, WCST (cat)	**MAS** (**Understanding one's own mind**, understanding other's mind, mastery)
Lysaker et al., (2007)	69	DSM-IV schizophrenia/schizoaffective	46.68(10.11)	11.59	Cross-sectional	WAIS III (A, V, BD, DS) WMS III (VR, LM), **WCST (cat**, per), BLERT (+ve, -ve emotions)	**MAS** (**Understanding one's own mind**, decentration)
Lepage et a., (2008)	51	FEP	23.2 (3.8)	29	Cross-sectional	WAIS III (DS, BD) **WMS III (VR**, LM, SS), TMT (A, B), ToL, d2, FFToSI, Hinting Test	**BCIS** (**SR**, SC, CI)
Lysaker et al., (2008)	49	DSM-IV schizophrenia/schizoaffective	49.63(5.71)	0	Cross-sectional	**DKEFS** (DF VF WS **ST** WC 20Q)	**MAS (Understanding one's own mind**, understanding other's mind, mastery), BCIS (CI)
Orfei et al., (2010)	60	DSM-IV schizophrenia	38(11.1)	38	Cross-sectional	Mental Deterioration Battery (RIR RDR CD CDL Pm 47 PVF SCT IVM **MWCST**) ROPDR, CROP, CF	**BCIS** (**SR**, SC, CI)
Lysaker et al., (2010b)	37	DSM-IV schizophrenia/schizoaffective	46.94 (10.77)	5.41	Cross-sectional	WCST (pers) HVLT	**MAS** (**Understanding one's own mind**, understanding other's mind, mastery)
Lysaker et al., 2010a)	102	DSM-IV schizophrenia/schizoaffective	46.54(9.37)	15	Cross-sectional	WAIS III (V DS), WMS III (VR), WCST (cat) HVLT (**composite score used in analysis**)	**MAS** (**mastery**)
Nicolo`et al., (2012)	45	DSM-IV schizophrenia/schizoaffective	38.18(11.2)	40	Cross-sectional	**WAIS III** (**V** DS), WMS III (VR), WCST (cat), RIR	**MAS** (**Understanding one's own mind**, understanding other's mind, mastery)
Hamm et al., (2012)	49	DSM-IV schizophrenia/schizoaffective	50.37(7.54)	10.2	Longitudinal	**WCST (cat)**, BLERT (total)	**MAS (total)**

Study	N	Diagnosis	Mean age (SD)	% female	Design	Cognitive domain(s)	Metacognitive domain(s)
Bruno et al., (2012)	28	DSM-IV schizophrenia	Delusional 35.07(6.86) Non-delusional 33.5(9.9)	32.14	Cross-sectional	**fNART** (V P **IQ**), WCST (cat rules pers SL)	**BCIS** (SR SC **CI**), WCST-meta (Q A FC G M C)
Giusti et al., (2013)	20	Schizophrenia diagnosis	36.2(9.8)	30	Cross-sectional	RCPM, RIR, RDR, WCFST, SST, Eyes **(Composite score used in analysis)**	**BCIS** (**SR** SC CI)
Lysaker et al., (2013)	95	DSM-IV schizophrenia/schizoaffective	49.36(8.7)	13.68	Cross-sectional	WAIS III (V), **WCST** (**cat**), BMERT (total), Eyes, Hinting test	MAS (total), BCIS (CI) (**metacognitive factor score used in analysis**)
Abu-Akel & Bo (2013)	42	ICD-10 schizophrenia	41.55(8.3)	50	Cross-sectional	**WAIS III (V)**	**MAS** (Understanding one's own mind, understanding other's mind, **total**)
Minor & Lysaker (2014)	68	DSM-IV schizophrenia/schizoaffective	50.5(10.38)	35.06	Cross-sectional	WAIS III (LNS) WMS III (SS), BACS (DS), HVLT, BVMT, CPT, TMT (A), CF, Neuropsychological assessment Battery mazes, MSCEIT (**composite score used in analysis**)	**MAS (total)**
Tas et al., (2014)	30	DSM-IV schizophrenia	34.43(8.56)	43.3	Cross-sectional	WMS (MQ), **WCST** (**cat** pers)	**MAS** (**Understanding one's own mind**, understanding other's mind, decentration, mastery)
Abu-Akel et al., (2015)	79	ICD-10 schizophrenia	36.86(10.37)	64	Cross-sectional	**WAIS III (V)**	**MAS** (Understanding one's own mind, understanding other's mind, mastery, **total**)
Luther et al., (2016)	175	DSM-IV schizophrenia/schizoaffective	48.67(9.9)	13	Cross-sectional	**WCST (cat)**, BLERT (total)	**MAS (total)**

Key: WAIS A=Arithmatic V=Vocabulary BD=Block Design DS=Digit symbolLNS=Letter-Number Sequencing; WMS VR=Visual Reproduction LM=Logical Memory SS=Spatial Span MQ=Memory Quotient; TMT=Trailmaking Task; d2= d2 Test of Attention; BACS DS=Digit Sequencing subtest; BVMT=Brief Visuospatial MemoryHVLT=Hopkins Verbal Learning Test; BLERT +ve=positive emotions –ve=negative emotions; FFToSI=Four Factor Tests of Social Intelligence; WCST cat=correct categories achieved rules=rules achieved per=perserveration responses ST=Set Loss; CF=Category Fluency test; CPT=Continuous Performance Test; DKEFS DF=Design Fluency switching VF=Verbal Fluency switching WS=colour Word Switching ST=Sorting Task WC=Word Context 20Q= 20 questions; Mental Deterioration Battery RIR=Rey's 15-word Immediate Recall RDR=Rey's 15-word Delayed Recall CD=Copy Drawings CDL=Copy Drawings with Landmarks PM

47=Raven's Progressive Matrices' 47 PVF=Phonological Verbal Fluency SCT=Sentence Construction test IVM=Immediate Verbal Memory MWCST=Modified Wisconsin Card Sorting test; ROPDR=Delayed Recall of Rey–Osterrieth picture; CROP=Copy of Rey–Osterrieth picture; CF=Category Fluency Test; RCPM=Raven's Coloured Progressive Matrices; WCFST=Weigl's Colour Form Sorting Test; SST=Strange Stories Test; Eyes=Reading the Mind in the Eyes Test; MSCEIT=Mayer-Salovey-Caruso Emotional Intelligence Test
MAS=Metacognitive Assessment Scale; BCIS SR=Self-reflectivity SC=Self-certainty CI=composite index; WCST-meta Q= Quantity A=Accuracy score FC=Free Choice improvement G=Global monitoring M=Monitoring resolution C=Control sensitivity. Variables inlcuded in meta-analysis indicated in bold font.

Table 2 Systematic review results table: Metacognition and functional outcome

Study	*N*	*Diagnosis*	*Mean Age (SD)*	*% female*	*Design*	*Metacognition measure*	*Outcome measure*
Gould et al., (2015)	214	SCID DSM-IV criteria schizophrenia/schizoaffective disorder	40 (12.4)	35	Cross-sectional	Wisconsin Card Sorting Task-meta (accuracy)	Specific Levels of Functioning (SLOF) scale (interpersonal function)
Abu-Akel & Bo, (2013)	42	ICD-10 diagnostic criteria for schizo- phrenia	41.55 (8.3)	50	Cross-sectional	Metacognition Assessment Scale (total)	Global Assessment of Functioning (total)
O'Connor et al., (2013)	127	DSM-IV criteria schizophrenia or related disorder, or affective disorder with psychotic features	29.75 (8.95)	31	Cross-sectional	Beck Cognitive Insight Scale	Global Assessment of Functioning (psychosocial)
Lysaker, Gumley et al., (2013)	95	DSM-IV criteria for schizophrenia	49.36 (8.7)	13.68	Cross-sectional	Metacognitive Awareness factor	Quality of Life Scale (Interpersonal relations)
Lysaker, McCormick et al., (2011a)	45	DSM-IV criteria for schizophrenia	48.50 (8.62)	10	Longitudinal	Metacognition Assessment Scale (mastery)	Functional capacity-UPSA (total)
Lysaker et al., (2010a)	102	DSM-IV criteria for schizophrenia	46.54 (9.37)	15		Metacognition Assessment Scale (mastery)	Quality of Life (interpersonal relations)
Stratta et al., (2009)	20	DSM-IV criteria for schizophrenia	35.2 (10.02)	15		Wisconsin Card Sorting Task-meta (accuracy)	Global Assessment of Functioning

Table 3: Individual cognitive domain analyses

Variable	Mean effect size	+/-95% Confidence Intervals	Heterogeneity Test Q	df	p	Number of Studies	Total Sample
Executive Functioning	.192	.078- .302	11.43	11	.408	12	718
Verbal IQ	.339	.212- .454	8.24	7	.312	8	456
Memory	.302	.178- .416	6.09	6	.413	7	343

Figures:

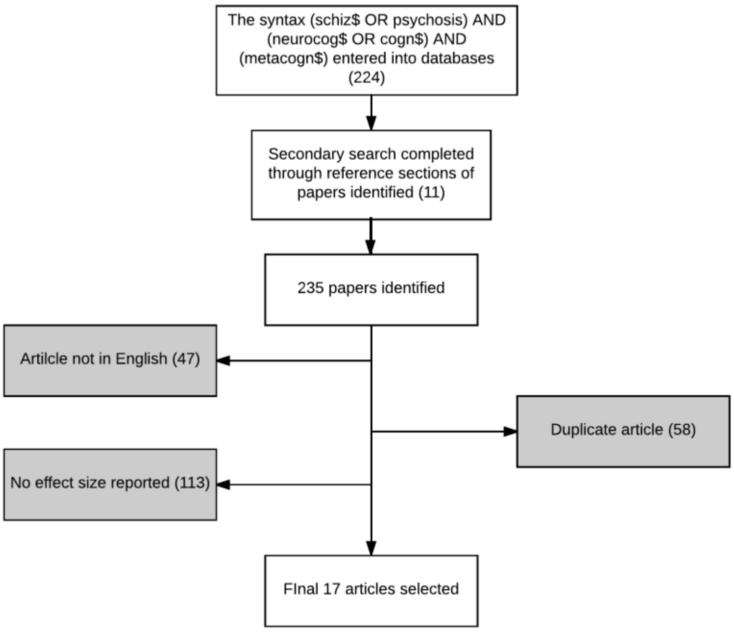

Figure 1 Neurocognition and metacognition search result consort diagram

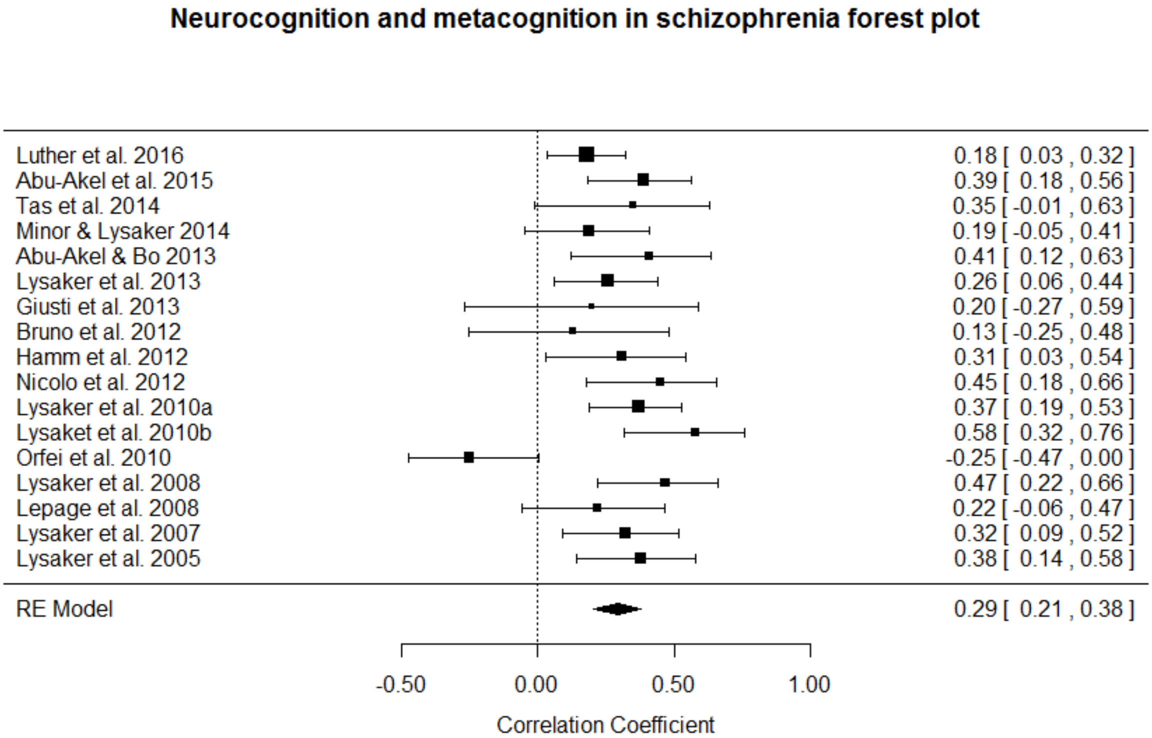

Figure 2 Cognition and metacognition forest plot

Figure 3 Funnel plot for the relationship between cognition and metacognition

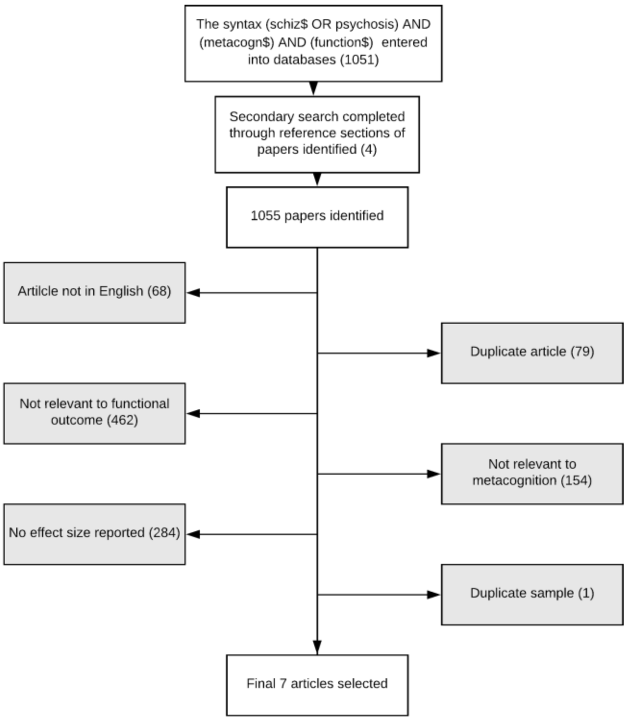

Figure 4: Search result consort diagram for metacognition and functional outcome

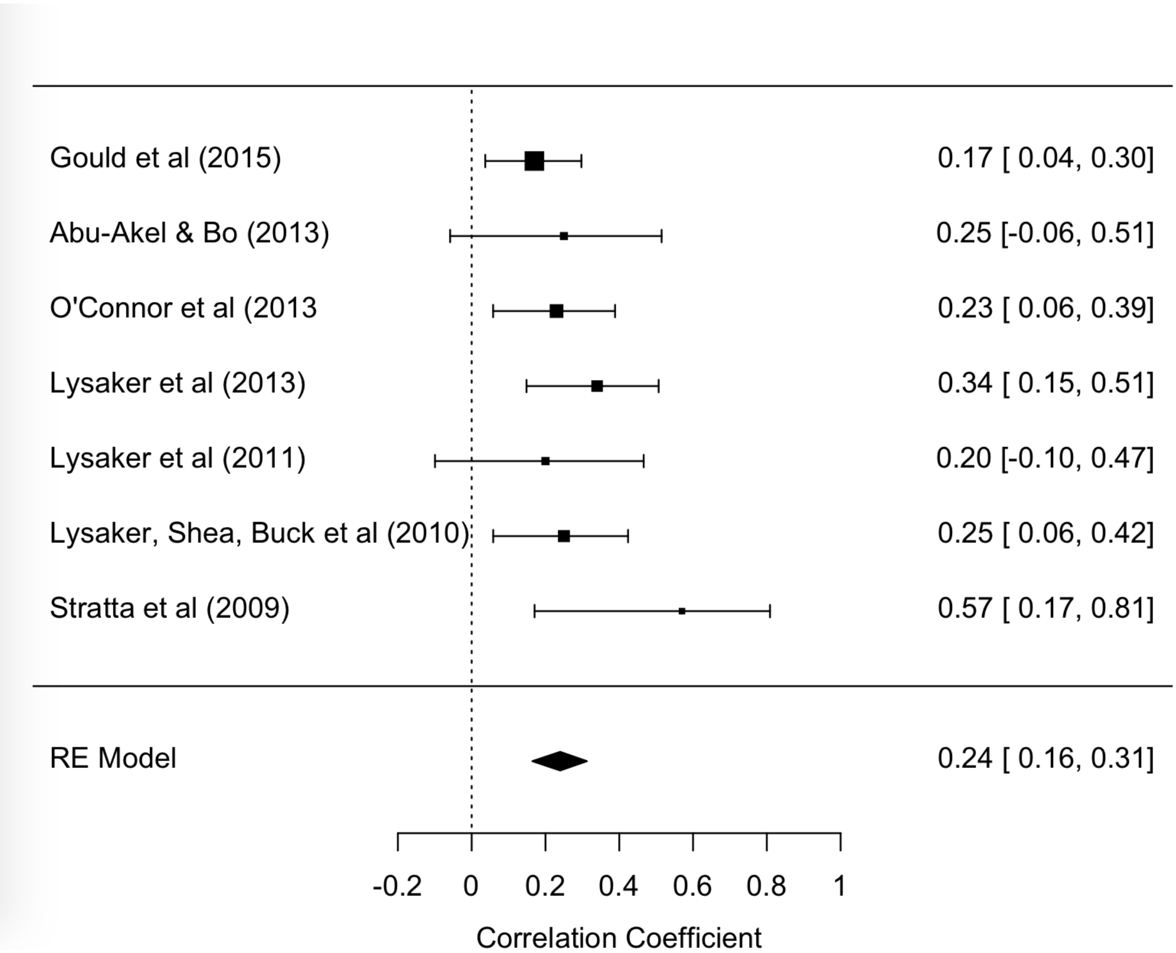

Figure 5 Metacognition and functional outcome forest plot (effect sizes and confidence intervals)

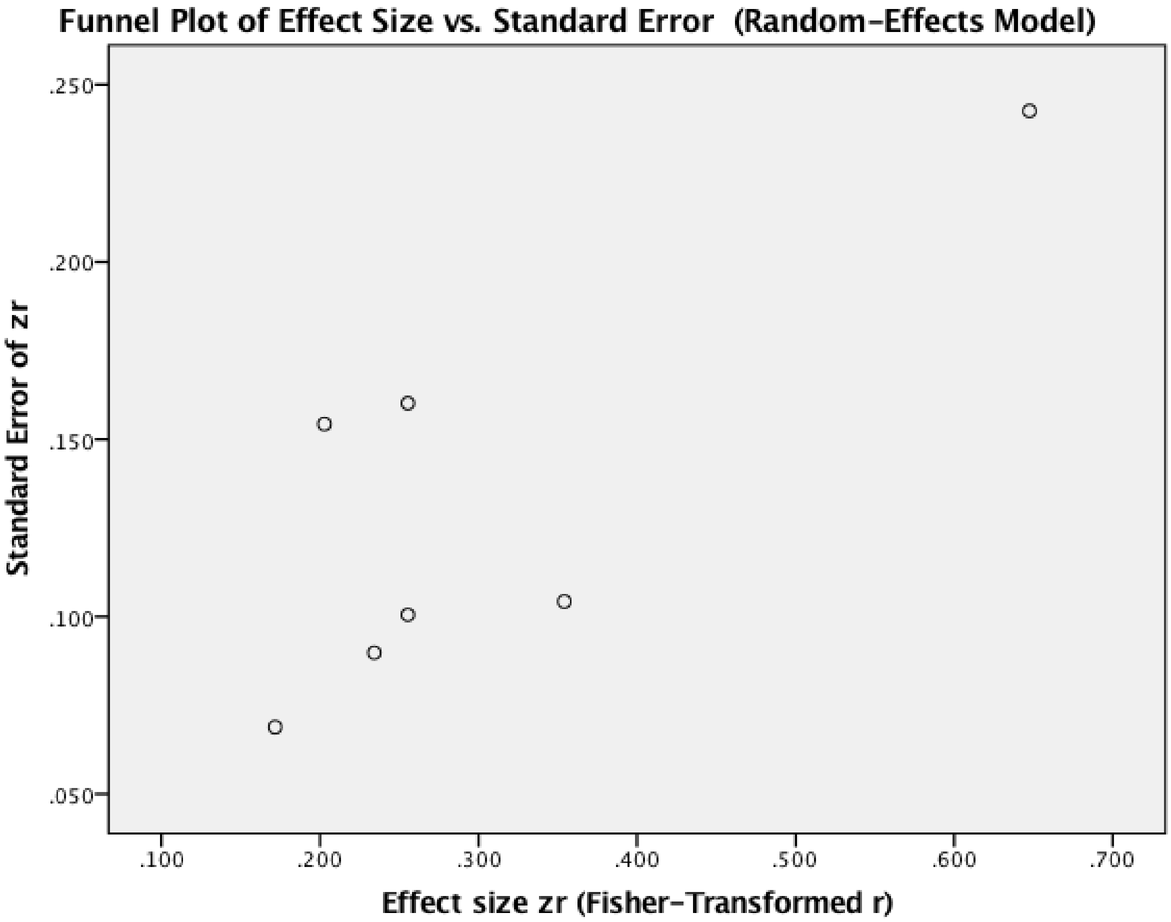

Figure 6: Funnel plot for metacognition and functional outcome